

PROGRAMMABLE RADIO RECEIVER BANDPASS FILTER FOR CORDLESS/WIRELESS SYSTEMS

BACKGROUND OF THE INVENTION

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FIELD OF THE INVENTION

The present invention relates to telecommunication systems and, particularly, to a system that is more robust against in-band interferers.

DESCRIPTION OF THE RELATED ART

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In conventional radio-frequency (RF) receivers, a band-pass filter is used to filter out-of-band interferers. In many cordless and/or wireless systems, the available bandwidth is subdivided into smaller channels. However, the band-pass filter typically has a bandwidth covering the entire available bandwidth.

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Such a receiver is illustrated more particularly in FIG. 1. The system 100 includes an antenna 101, a band-pass filter 102, a mixer 104, a voltage-controlled oscillator 106, a band-pass filter 108, a demodulator 110, a low-pass filter 112, and a synchronization block 114.

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A modulated signal is received at the antenna 101 and is band-pass filtered by the band-pass filter 102. The band-pass filter 102 reduces the receiving signal bandwidth to the bandwidth that covers all the used channels.

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By doing so, the band-pass filter 102 filters out the out-of-band interference. The signal output from the band-pass filter 102 is mixed in the mixer 104 with a lower constant frequency signal which may be generated, as shown, by the voltage controlled oscillator 106. The modulated receive signal is thus transferred down to a lower frequency, typically referred to as the Intermediate Frequency (IF). The band-pass filter 108 is provided behind the mixer 104 because the output of the mixer 104 is two down-converted modulated receive signals on two different frequencies, only one of which can be used in the demodulator 110. Thus, only one of the down-converted IF signals is passed through the band-pass filter 108 to the demodulator 112. The demodulator 110 converts the frequency-modulated signal into a

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baseband signal, which is low-pass filtered using the low-pass filter 112. Finally, the sync block 114 synchronizes to the low-pass filtered signal. For example, the synchronization block may detect one or more synchronization words.

5 As can be appreciated, when the signal bandwidth is less than the available system bandwidth, the band-pass filter 102 fails to filter out the "out of channel" interferers. These are then mixed and can negatively impact system robustness, which results in a higher bit error rate and voice quality degradation.

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SUMMARY OF THE INVENTION

These and other problems in the prior art are overcome in large part by a system and method according to the present invention. A programmable band-pass filter is provided in a radio-frequency receiver. The band-pass
15 filter has a bandwidth substantially covering only a channel bandwidth. Once the appropriate channel in use is determined, the frequency band of the band-width filter is set to correspond to it.

The receiver may be used in direct sequence or frequency hopping spread spectrum cordless telephone systems. One such frequency hopping
20 system includes a base station and one or more handsets. The handsets lock onto the base station to synchronize with the frequency hopping scheme. The receivers in the base station and the handsets set their band-pass filter bandwidths according to the frequency of the frequency hopping scheme.

According to one implementation of the invention, a channel selector of
25 a base station selects a frequency according to a frequency hopping scheme.

The channel selector provides the frequency to the base station's receiver for the channel band-pass filter. The base station provides control data to the handsets' channel selectors, which lock to the frequencies being hopped-to by the base station. The handsets' channel selectors then provide this
30 information to the bandpass filters of their receivers, which then filter the band of the frequency chosen.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the invention is obtained when the following detailed description is considered in conjunction with the following drawings in which:

5 FIG. 1 is a diagram illustrating a radiofrequency receiver according to the prior art;

 FIG. 2 is a block diagram of an exemplary radiofrequency receiver according to an implementation of the present invention;

 FIG. 3 is a diagram illustrating exemplary bandwidth selection;

10 FIG. 4 is a diagram of an exemplary frequency hopping cordless telephone system according to an implementation of the invention;

 FIG. 5 is a diagram of exemplary frame frequencies for a frequency hopping cordless telephone system according to an implementation of the invention;

15 FIG. 6 is a diagram illustrating exemplary subdividing a frequency band according to an implementation of the invention; and

 FIG. 7 is a flowchart illustrating operation of an implementation of the invention.

20 DETAILED DESCRIPTION OF THE INVENTION

 FIGS. 2- 7 illustrate a telecommunications system including telecommunications devices according to an implementation of the present invention.

25 FIG. 2 is a diagram of an exemplary receiver in accordance with an implementation of the present invention. The receiver 200 includes an antenna 201, a band-pass filter 202, a mixer 204, a voltage-controlled oscillator 206, a band-pass filter 208, a demodulator 210, a low-pass filter 212, and a synchronization block 214. As will be explained in greater detail below, both the VCO 206 and the band-pass filter 202 receive frequency
30 select inputs 216, defining the frequency and frequency band that is to be used. The band-pass filter 202 then adjusts the band for band pass filtering accordingly.

A modulated signal is received at the antenna 201 and is band-pass filtered by the band-pass filter 202. The band-pass filter 202 reduces the receiving signal bandwidth to the bandwidth that covers substantially only the channel currently in use, responsive to the frequency select signal. By doing
5 so, the band-pass filter 202 filters out the out-of-band interference. The frequency select signal is provided from a processor 216 which determines the channel in use, by any of a variety of methods.

The signal output from the band-pass filter 202 is mixed in the mixer 204 with a lower constant frequency signal which may be generated, as
10 shown, by the voltage controlled oscillator 206. The modulated receive signal is thus transferred down to the Intermediate Frequency (IF). Again, a second band-pass filter 208 is provided behind the mixer 204 because the output of the mixer 204 is two down-converted modulated receive signals on two different frequencies, only one of which can be used in the demodulator 210.
15 Thus, only one of the down-converted IF signals is passed through the band-pass filter 208 to the demodulator 210. The demodulator 210 converts the frequency-modulated signal into a baseband signal, which is low-pass filtered using the low-pass filter 212. Finally, the sync block 214 synchronizes to the low-pass filtered signal.

20 Operation of the programmable band-pass filter is illustrated more particularly in FIG. 3. Shown are an available frequency band fb, subdivided into a plurality of channels fc1-fc7. It is noted that, in practice, a substantially larger number of channels are available. Thus, FIG. 3 is exemplary only. As will be described in greater detail below, communication occurs over one of
25 the channels fc1-fc7. As described above, the bandwidth of the band-pass filter 208 (FIG. 2) is set to one of the channel bandwidths fc1-fc7, once it is determined which channel is in use.

The receiver 200 of FIG. 2 is suitable for use in any radio-frequency system. FIG. 4 is a block diagram of one implementation of an exemplary
30 radio-frequency system according to the present invention. In particular, the system may be implemented as a frequency hopping cordless telephone system, indicated generally as 10. System 10 includes one or more base

stations 12, each of which can also be referred to as a fixed part (FP). Each base station 12 can support communication with a plurality of handsets 14 and handsets 16 using radio frequencies. The interface between base station 12 and handsets 14 and 16 can be referred to as the air interface. Handsets 14 and handsets 16 can also be referred to as portable parts (PP). The base station 12 and the handsets 14 and 16 further include receivers 200 according to the present invention as well as channel selectors 40, 41, as will be described in greater detail below. An exemplary system suitable for use with a receiver according to the present invention is the Gigaset system, available from Siemens Corp.

In operation, base station 12 can support a defined total number of handsets 14 and 16. For example, in one implementation, base station 12 can support a total of eight handsets, either idle locked or active locked. Of the total number of handsets, a given number "M" can be active locked handsets 16. For example, base station 12 could support up to four active locked handsets 16 from the eight total handsets. Of the remaining handsets, base station 12 can support a given number "N" of idle locked handsets 14. For example, "N" can be less than or equal to the difference between the total number of supported handsets (e.g., 8) and the number "M" of active locked handsets 16 (e.g., 0-4). Idle locked handsets 14 are handsets that are currently inactive but are in contact with and in sync with base station 12.

Base station 12 can communicate with handsets 14 and handsets 16 using a time division multiplexed (TDM) frame-based communication protocol. For example, each frame can be ten milliseconds (10 ms) in duration and can include transmit and receive channels for communication and control data. One protocol used with digital cordless telephone systems is the Digital Enhanced Cordless Telecommunications (DECT) protocol, which is the pan-European standard for digital cordless systems and supports up to six locked handsets 16 (i.e., M=6). There are, of course, other protocols used for communicating across the air interface between base station 12 and handsets 14 and handsets 16. For example, the DECT protocol can be modified to support up to four locked handsets 16 (i.e., M=4), each with

enhanced communication features due to higher data rates.

In the implementation of FIG. 4, system 10 uses an ISM band of radio frequencies for supporting communication between base station 12 and handsets 14 and 16. For example, system 10 can use the ISM band
 5 extending from 2.4 GHz to 2.4835 GHz. An advantage of using the ISM band is that it is unlicensed and does not require a license fee for use. However, in order to operate within FCC or other government regulations, system 10 implements a frequency hopping scheme. This allows system 10 to support robust cordless communications in the ISM band while operating within
 10 regulation guidelines. Under the frequency hopping scheme, base station 12 and handsets 14 and 16 move in the time domain from frequency to frequency. Because of the changing frequency, handsets are initially in an unlocked state when entering an area serviced by base station 12. Unlocked handsets can then "listen" at a specific radio frequency to attempt to lock on
 15 to base station 12. When base station 12 hops to that frequency specific frequency, unlocked handsets can identify and receive control data transmitted by base station 12. This allows unlocked handsets to lock with base station 12 and sync with the frequency hopping scheme. As will be described in greater detail below, the control data used to synchronize to the
 20 frequency are also used to synchronize the band-pass filter.

FIG. 5 is a block diagram of one embodiment of frame frequencies for a frequency hopping cordless telephone system. As shown, a frame structure, indicated generally at 20, comprises a plurality of frames 22 each having a frame length 24. Each frame 22 follows immediately after the previous frame
 25 22 in the time domain. In the embodiment of FIG. 4, a different frequency ($F_1, F_2, F_3 \dots F_N, F_{N+1}, \dots$) is associated with each frame 22 and is used during that frame 22 for communication across the air interface between base station 12 and handsets 14 and 16. This change from frequency to frequency is handled by the frequency hopping scheme implemented by base station 12
 30 and handsets 14 and 16. During the duration of a given frame 22, base station 12 and handsets 14 and 16 communicate using the selected frequency for that frame 22. When the next frame 22 begins, base station 12

and handsets 14 and 16 communicate using a new selected frequency. In one embodiment, frame length 24 is ten milliseconds. Thus, the frequency being used changes every ten milliseconds, as does the frequency band of the band-pass filter 202.

5 FIG. 6 is a diagram of one embodiment of subdividing the ISM band for a frequency hopping cordless telephone system. The ISM band used in this embodiment extends from 2.4 GHz to 2.4835 GHz. As mentioned, the FCC defines requirements for use of frequencies within the ISM band. For example, within a 30 second period, the regulations limit the maximum length
10 of time that a system can use one frequency to 0.4 seconds. Thus, the total available frequencies needs to include seventy-five or more frequencies. In the embodiment of FIG. 6, this range is divided into twelve subsets 30, and each subset 30 is divided into eight channels 32. Each channel 32 is then associated with one of ninety-six frequencies 34 defined within and equally
15 subdividing the ISM band. Frequencies 34 then provide a set of frequencies from which the frequency hopping scheme can select for each frame 22.

The frequency hopping scheme, in addition to selecting frequencies, also needs to implement a scheme for avoiding bad frequencies. For example, a PCS microwave tower may interfere with frequencies in the ISM
20 band in a particular region. Thus, cordless telephone system 10 would not want to use those frequencies. One way to avoid such bad frequencies is to block their selection. By dividing the ISM band into ninety-six frequencies, the embodiment of FIG. 6 provides sufficient frequencies to allow bad frequencies to be blocked while keeping the number of available frequencies
25 above the seventy-five frequency threshold. For example, there is freedom to avoid using the frequencies within two subsets 30 without dropping below the seventy-five frequency threshold.

The channel selector 40 of the base station 10 may implement a frequency hopping selection system that selects a frequency for
30 communication between a base station 12 and one or more handsets 16. A similar selection system 41 resides in handset 16. Selection systems 40 and 41 must be operable to select the same frequency for a given frame, such

that base station 12 and handset 16 can continue communication while hopping frequencies. The channel selectors 40, 41 may implement any of a variety of frequency hopping schemes. One such scheme is described in U.S. Patent Application Serial No. 09/113,539, filed July 10, 1998, titled

5 "Method and System for Table Implemented Frequency Selection in a Frequency Hopping Cordless Telephone System," which is hereby incorporated by reference in its entirety as if fully set forth herein.

According to one implementation of the invention, the channel selector 40 selects a frequency according to a frequency hopping scheme. The

10 channel selector 40 provides the frequency to the receiver 200 for the band-pass filter 202. The base station provides control data to the handsets' channel selectors 41, which lock to the frequencies being hopped-to by the base station 10. The channel selectors 41 then provide this information to the bandpass filters of their receivers 200, which then filter the band of the

15 frequency chosen. The channel selectors 40, 41 may be implemented as one or more processors or integrated circuits 216 (FIG. 2).

This is illustrated more particularly with reference to the flowchart of FIG. 7. In a step 702, the base station 10's channel selector 40 implements a frequency hopping scheme, and selects frequencies for use during the

20 communication. For example, the channel selector 40 may first select particular frequency subsets (FIG. 4) and then individual channels in each subset. In a step 704, the base station provides the sequence, or the particular frequency, as a frequency select signal to the band pass filter 202. The band pass filter 202 then selects that channel for filtering, in a step 706.

25 In a step 708, the base station provides control signaling to the handset(s), which then lock to the frequency hopping scheme, in a step 710. For example, the handset may listen on a particular frequency. When the base station transmits data on that frequency, the handset detects it and can lock to the frequency hopping scheme. In a step 712, the handset's channel

30 selector 41 provides the frequency (or hop scheme) to the bandpass filter of its receiver. In a step 714, the band pass filter's band is adjusted to the currently selected channel.

The invention described in the above detailed description is not intended to be limited to the specific form set forth herein, but is intended to cover such alternatives, modifications and equivalents as can reasonably be included within the spirit and scope of the appended claims.

100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387 388 389 390 391 392 393 394 395 396 397 398 399 400 401 402 403 404 405 406 407 408 409 410 411 412 413 414 415 416 417 418 419 420 421 422 423 424 425 426 427 428 429 430 431 432 433 434 435 436 437 438 439 440 441 442 443 444 445 446 447 448 449 450 451 452 453 454 455 456 457 458 459 460 461 462 463 464 465 466 467 468 469 470 471 472 473 474 475 476 477 478 479 480 481 482 483 484 485 486 487 488 489 490 491 492 493 494 495 496 497 498 499 500 501 502 503 504 505 506 507 508 509 510 511 512 513 514 515 516 517 518 519 520 521 522 523 524 525 526 527 528 529 530 531 532 533 534 535 536 537 538 539 540 541 542 543 544 545 546 547 548 549 550 551 552 553 554 555 556 557 558 559 560 561 562 563 564 565 566 567 568 569 570 571 572 573 574 575 576 577 578 579 580 581 582 583 584 585 586 587 588 589 590 591 592 593 594 595 596 597 598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 613 614 615 616 617 618 619 620 621 622 623 624 625 626 627 628 629 630 631 632 633 634 635 636 637 638 639 640 641 642 643 644 645 646 647 648 649 650 651 652 653 654 655 656 657 658 659 660 661 662 663 664 665 666 667 668 669 670 671 672 673 674 675 676 677 678 679 680 681 682 683 684 685 686 687 688 689 690 691 692 693 694 695 696 697 698 699 700 701 702 703 704 705 706 707 708 709 710 711 712 713 714 715 716 717 718 719 720 721 722 723 724 725 726 727 728 729 730 731 732 733 734 735 736 737 738 739 740 741 742 743 744 745 746 747 748 749 750 751 752 753 754 755 756 757 758 759 760 761 762 763 764 765 766 767 768 769 770 771 772 773 774 775 776 777 778 779 780 781 782 783 784 785 786 787 788 789 790 791 792 793 794 795 796 797 798 799 800 801 802 803 804 805 806 807 808 809 810 811 812 813 814 815 816 817 818 819 820 821 822 823 824 825 826 827 828 829 830 831 832 833 834 835 836 837 838 839 840 841 842 843 844 845 846 847 848 849 850 851 852 853 854 855 856 857 858 859 860 861 862 863 864 865 866 867 868 869 870 871 872 873 874 875 876 877 878 879 880 881 882 883 884 885 886 887 888 889 890 891 892 893 894 895 896 897 898 899 900 901 902 903 904 905 906 907 908 909 910 911 912 913 914 915 916 917 918 919 920 921 922 923 924 925 926 927 928 929 930 931 932 933 934 935 936 937 938 939 940 941 942 943 944 945 946 947 948 949 950 951 952 953 954 955 956 957 958 959 960 961 962 963 964 965 966 967 968 969 970 971 972 973 974 975 976 977 978 979 980 981 982 983 984 985 986 987 988 989 990 991 992 993 994 995 996 997 998 999 1000